

DESIGNER'S FORUM

Design and construction of geosynthetic-reinforced lagoon caps—part II

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IN THE PREVIOUS DESIGNER'S Forum (April, p. 21), we outlined the basic design steps for a geotextile-reinforced lagoon cap. In this article, we review the construction of the cap and highlight the significant interaction required between design and construction. Unlike other civil-engineering structures, it is not possible to design a geotextile-reinforced cap without understanding or limiting the manner in which it can be constructed. This point is very important and is a common reason why many contractors and engineers are uncomfortable with contractual requirements for such projects.

In addition to discussing the design-construction relationship, this article also includes construction techniques for improving the performance of this procedure. These guidelines have been compiled based on the authors' previous project experience and the referenced technical papers.

Design-based equipment requirements

We previously reviewed the design of the initial drainage layer placed over the geotextile. We showed that thickness is determined by localized bearing-capacity considerations and that geotextile strength is determined by global-stability considerations. The global-stability calculation is influenced significantly by the weight of the bulldozer assumed in the analysis.

Assuming the sludge has a constant cohesive strength, c , the factor of safety against deep failure is given approximately as follows:

$$FS_{Global} = \frac{tT_{GEO} + c(T_W + 2t)(\pi T_L - 2t)T_L}{T_L/2 * W/2}$$

where T_W , T_L , and W are the track width, length and weight of the bulldozer, t is the thickness of the first lift, and T_{GEO} is the tension in the geotextile. The tension in the

geotextile for three different bulldozer assumptions and a range of sludge shear strengths is shown in Figure 1. This dramatic relationship between fabric tension and bulldozer weight requires the designer to limit the equipment used in the initial construction of such covers. Sludge consolidation under the weight of the cap will increase its shear strength and may eliminate such traffic restrictions in the future.

Geotextile fabrication and deployment

The actual sequence of construction required to successfully place a geotextile-reinforced cap over soft sludges should be based on the successful techniques outlined below. While the engineer may feel compelled to include these guidelines within the project specifications, the authors recommend providing them as a non-binding attachment to the specifications. This provides the contractor with construction background information, but does not limit flexibility in the field.

The geotextile panels can be fabricated using the following guidelines:

1. Prefabricate the geotextile reinforcement in one large panel with the machine direction parallel to the longest dimension of the lagoon (pond). This ensures that the machine (strongest) direction is perpendicular to the direction of fill placement/propagation across the shortest dimension.
2. The geotextile should be fabricated using a seaming technique that would leave the entire panel in an accordion fold for deployment at the project site (see Figure 2a).
The geotextile panel can be fabricated at a factory or on-site. Seaming the main geotextile in place on the soft soil is not recommended, unless the soft soil can support foot traffic and all-terrain vehicles without artificial aides. If the geotextile is sewn on the soft soil, the sewing should be performed at least 15.2 m (50 ft) in front of the nearest fill-placement activity.
3. If drainage at the geotextile/sludge interface is required, drainage pipes can be sewn into the seams to aid in removal of the liquid.

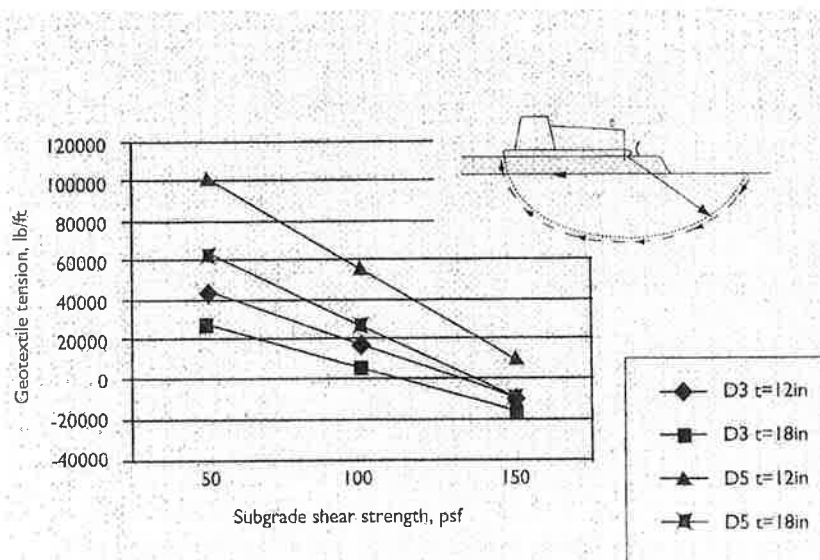


Figure 1. Geotextile tension and sludge shear strengths.

The geotextile manufacturer typically will assist the contractor in demonstrating that the required seam strength is achieved and in determining the optimum seaming technique. The designer should limit involvement in this process to simply specifying the minimum seam strength required based on design considerations.

Deployment of the reinforcing geotextile obviously will be influenced by the ability to work on top of the sludge. If the sludge is too weak to support traffic, then the geotextile should be deployed as follows:

1. The geotextile should be positioned over the lagoon using a pulling rope (cables—see Figure 2a.) The ropes should be attached to the geotextile with a knot at sufficient locations to minimize stress concentrations from the pulling process. The amount of force required to pull the geotextile across will vary based on the weight of the geotextile and the frictional resistance along the top of the pond. Softballs are ideal for tying the pulling rope onto the geotextile. Cables attached to C-clamps also work. Typically a maximum of 30.5 m (100 ft) spacing is used between the pull points.
2. Constant speed of the deployment equipment, with no sudden jerks, is necessary to minimize deployment stresses on the geotextile. This is particularly important when transitioning between areas of sludge and water. The leading edge of the geotextile should be hoisted as high as possible to minimize drag on the lagoon surface. Particular attention must be paid to minimizing deployment stresses on windy days. Two-way radios can aid in the coordination of deployment operations.
3. If the lagoon is too long to deploy the geotextile in one pass, multiple passes can be accomplished by reattaching the deployment equipment to the midpoint of the geotextile panel. In this case, the leading edge of the geotextile panel is left in place at the end of the initial pull.
4. Because polypropylene geotextiles are lighter than water, it is easier to place them when there is water on top of the soil/sludge. Remove debris within the lagoon, such as glass, roots, metal and bushes, that could catch or damage the geotextile. Another prudent option would be to temporarily fill the lagoon with water before placing the geotextile. This also provides much greater flexibility for moving the geotextile into the final placement position, and eliminating wrinkles that could minimize membrane tension.
5. Unlike polypropylene geotextiles, polyester geotextiles are heavier than water and will sink. They require artificial buoyancy to deploy geotextiles over water or liquids. If the placement procedure takes less than two hours, put floats underneath the fabric at the lead pulling edge.
6. Try to remove all wrinkles from the geotextile panel prior to fill placement. To do this, tension the geotextile toward the anchorage location (trench). Winches or deployment equipment attached to the geotextile can be used to pull the geotextile taut.
7. Whether naturally present or pumped in, the water should be removed from the lagoon prior to using tractors for fill placement. Water may remain if fill is deployed from draglines, clamshells, or barges float-

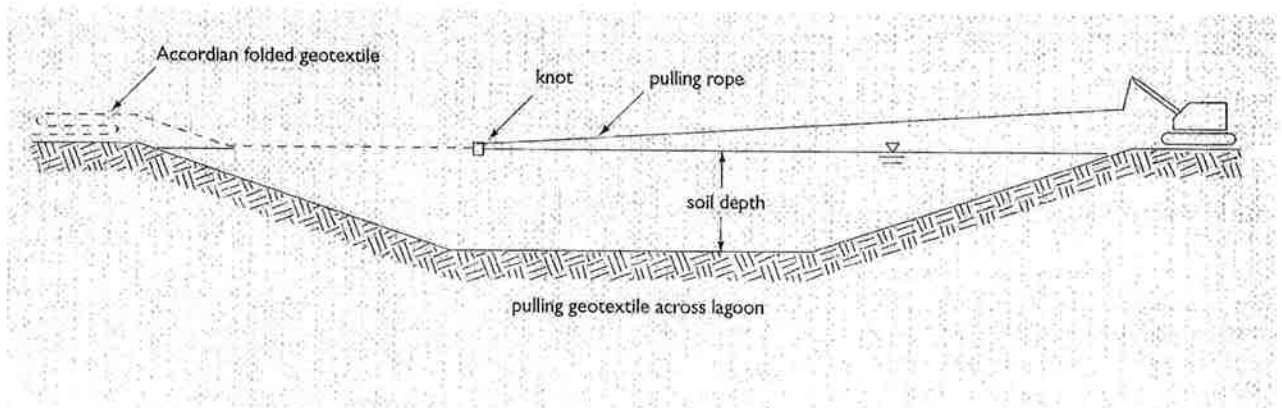


Figure 2a. Geotextile-installation methods for lagoon closure (Hoekstra and Berkout 1990, Risseeuw and Voskamp 1993).

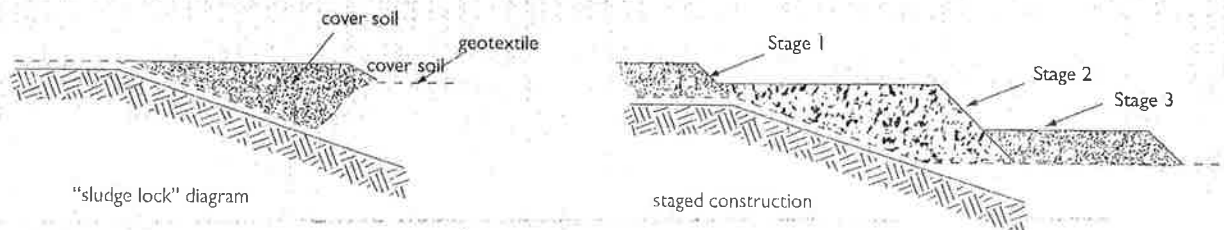


Figure 2b. Sandbags or an extra layer of soil can create a "sludge lock" to anchor the edge of the geotextile (Hoekstra and Berkout 1990, Risseeuw and Voskamp 1993).

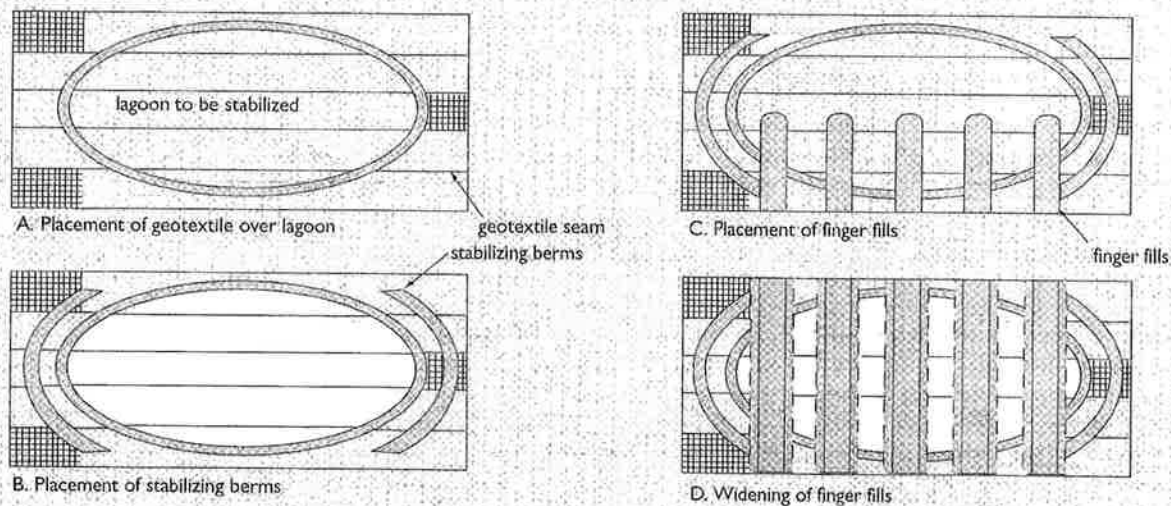


Figure 3a. Put a stabilizing berm or perimeter layer of soil on the fabric to prevent the soft materials from squeezing out between the geotextile and fill. A geotextile-placement technique known as "finger" fills has been used successfully on many projects.

ing in the lagoon, or if the fill is hydraulically placed. Fill-placement operations may need to be coordinated with the lagoon dewatering if liquids are to be decanted. This minimizes strong odors.

8. The geotextile should be fully anchored on at least two opposite sides and sometimes around the entire perimeter of the lagoon before placing any interior fill. At a minimum, sandbags should be used to

anchor any geotextile edge that will not be covered with soil. As part of the anchoring procedure, a sludge lock (Figure 2b, p. 15) can be incorporated by encroaching slightly (<1 m [3 ft]) on the

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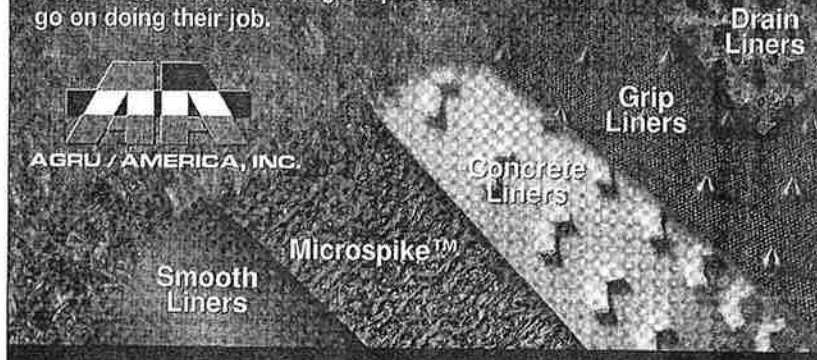
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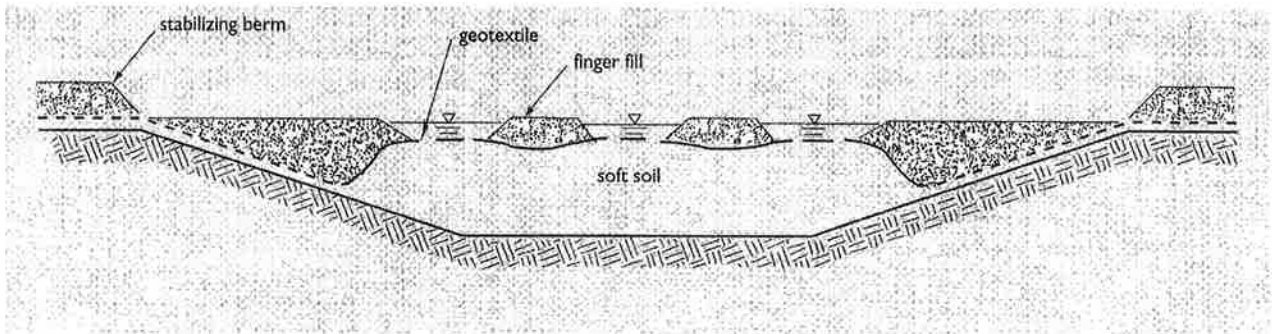


Figure 3b. Fill-placement procedures for soft-soil stabilization with geotextiles. (Broms 1987)

soft material prior to covering the remaining anchorage length. To do this, put a stabilizing berm or perimeter layer of soil on the fabric to prevent the soft materials from squeezing out between the geotextile and fill (Figure 3a).

Frequently, desiccation of the sludge provides a thin surface crust that is strong enough to support geotextile placement. In this case, if deployment of additional geotextile panels or layers of geotextile are necessary and will require travel over previ-

ously deployed geotextiles, a rubber-tired vehicle is recommended.

Fill placement

The "moment of truth" for the contractor is when he or she places the initial drainage lift over the geotextile. His ability to place it without generating excessive mudwaves or damaging the fabric is critical. The following guidelines are provided for placement of this initial lift:

1. For conventional fill-placement procedures, low-ground pressure (LGP) equipment is required. As discussed in the introduction, be sure to include this specification in the construction specifications to make the contractor aware of this necessary special equipment. LPG equipment usually refers to small bulldozers (preferably D-3 or D-4—the total weight is critical) with wide tracks that exert less than 34.5 kPa (5 psi) ground pressure.

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- The fill should be stockpiled in the anchorage zone (the area where fabric runs out beyond the sludge) and carried or pushed out onto the soft soil in thin (300 mm [12 in]) lifts. The thin lifts are necessary to reduce mud waving. Mud waving is considered a problem if the geotextile in front of the fill placement rises above the height of the fill.
- To maximize the tension-membrane benefits of the geotextile, try to maintain uniform tension in all areas of the geotextile by controlling fill placement. A placement technique known as "finger" fills (Figures 3a and 3b) has been used successfully on many projects. This controls mud waving by containing the displacement of the soft material between the "finger"

fills. A typical finger fill is the width of one crawler-bulldozer pass, and the initial clear-distance spacing between fingers is two to four bulldozer widths. This technique can be optimized by creating finger fills from the lagoon perimeter inwardly instead of filling from only one side. Figure 3b details this operation.

Once the first finger fills are completed across the lagoon, the second-pass fingers can be placed between the initial fingers. The first lift is then completed by filling the remaining open areas after completion of the second pass fingers, evenly from the finger berms, (Figure 3a).

- The softness of the underlying soils will dictate fill-placement procedures for the second lift. However, it usually is best to use the finger-fill technique for the second lift. Riding over well-graded to coarse sand and gravel with the bulldozer is usually enough to compact the first two lifts. For most projects, the third lift usually can be placed using conventional earthwork equipment and compaction procedures.

- Measure the volume of fill by recording the delivery or importation fill quantities. Due to settlement in the soft materials, surveying surface elevations is inadequate for pay quantities, unless there are also supplemental settlement plates to determine the final in-place elevation of the geotextile.

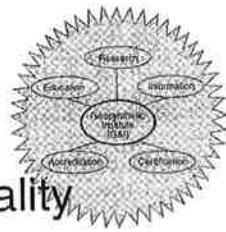
- Allow sufficient time for the soft materials to experience primary consolidation prior to constructing a permanent structure, such as a geomembrane cap or parking lot on the soil cap. To determine the end of primary consolidation, use instrumentation, such as settlement plates and pore-pressure transducers.

If the timeline for construction of permanent structures above the stabilized soil/sludge is critical, read these geotechnical instruments frequently to provide pertinent data for assessing the completion of primary consolidation.

The importance of sludge consolidation to the final performance of the cap cannot be overstated. Without consolidation of the weak sludges, future truck traffic over the cap would be impossible. The designer must determine



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